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Heat Distribution in Burning Cement Clinker

A Technical Analysis

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Burning of cement clinker has been the subject of many papers written on the manufacture of portland cement. Most of such papers, however, have discussed the subject from the viewpoint of the chemist, and those papers which have discussed the subject from the engineer's viewpoint have for the most part confined themselves to descriptions of equipment or to the partial summing up of heat distribution and balance. The writers of this paper were impressed with the apparent inefficiency of the operation of the kilns coming under their observation in several cement plants and the lack of definite control of the several variable factors in the practical operation of the kilns. The reports coming in from several plants seem to reflect the individual capacity of the superintendent of each plant rather than a definite knowledge of the subject. The writers, therefore, concluded to start a careful study of the subject with a view of devising some means of definite control for as many as possible of the variable conditions, in order to improve both the efficiency of operation and uniformity of product.

When the theoretical amount of coal required to burn one barrel of cement was compared with the actual amount consumed, it was quite apparent that the equipment in use was very inefficient.

The opportunity presented itself for making observations on the operation of a rotary kiln working under normal conditions, and the subject matter of this paper will present a brief description of the data observed, a discussion of the efficiencies and possible manner for increasing same in the present equipment for burning cement clinker, and the discussion showing distribution in the combustion zone of the heat units of the powdered coal used.

The original object of the experiment was to determine the adaptability of the recording pyrometers and combustion recorders to the practical operation of a rotary cement kiln. In order to make the observations for a careful study of the subject, a rotary kiln 8 ft. in diameter by 100 ft. long operating under the wet process was equipped with pyrometers and a gas analyzer.

Pyrometry

The kiln was equipped with indicating and recording pyrometers at different points along its length, as in Fig. 1. Five thermo-couple tubes were installed at stations 2, 3, 4, 5, and 6, so arranged by means of conductors, collector rings and brushes that the temperatures could be recorded from any of these stations at one time. A separate thermo-couple was installed at station No. 1 in the dust chamber so as to measure the temperature of the gases leaving the kiln before these gases were diluted by the air drawn into the stack around the end of the kiln.

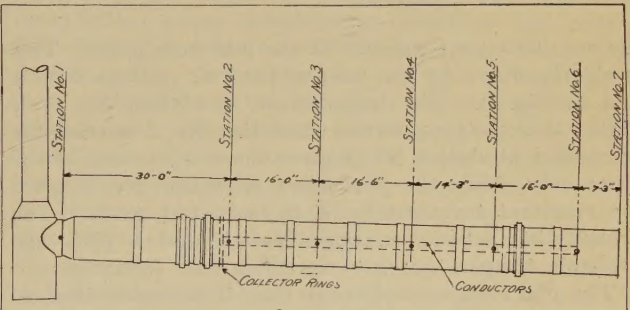
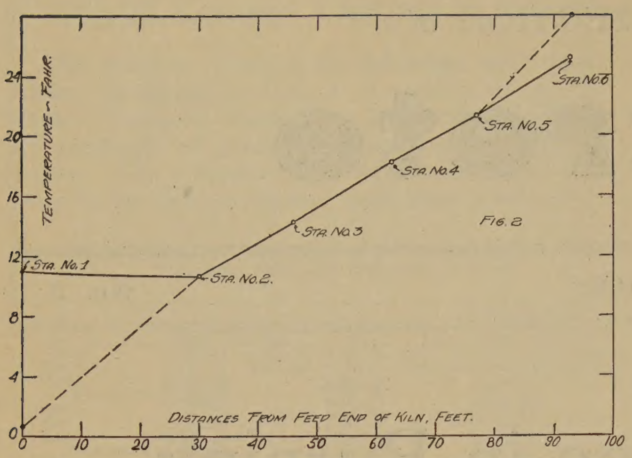


Fig. 1—Location of Collector Rings, Conductors and Thermo—Couple Tube

The thermo-couple at station No. 1 remained connected to its instrument during the entire time of making observations; but thermo-couple for measuring the temperatures at stations Nos. 2 to 6, inclusive, was inserted in one tube at a time and remained in each tube, except at station No. 6, about 72 hours. The intense heat and the fluxing and abrasive action of the clinker at station No. 6 destroyed the thermo-couple tube in about five hours, so that it was not safe to leave the thermo-couple in the tube over four hours. It was necessary to let the kiln cool several hours before installing a tube at station No. 6, and since the pyrometer instrument indicated that the temperature was still rising when the thermo-couple was removed from the tube, the temperature recorded for this station is too low.

The thermo-couple tubes projected into the kiln about 9 in. beyond the inner surface of the kiln lining and since the tubes were entirely covered by the mix fully one-eighth of the time, the temperatures recorded are



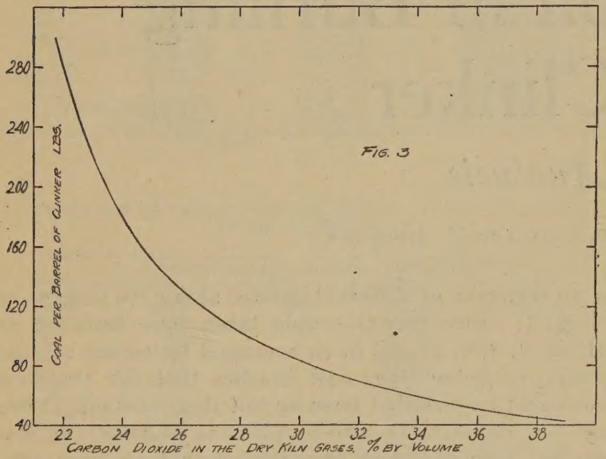


Fig. 2—Curve Giving the Resultant Temperature of the Mix and Gases as Given by Pyrometers

Fig. 3—Curve Giving the Relation Between Kiln Coal per Barrel of Clinker and Carbon Dioxide in the Dry Kiln Gases Per Cent by Volume

the resultant temperatures of the mix and gases. This is clearly shown by the temperatures at stations Nos. 1 and 2, Fig. 2. The temperature at station No. 1 is higher than the temperature at station No. 2 because the pyrometer at station No. 1 gives the temperature of the gases only, while the pyrometer at station No. 2 gives the resultant temperature of the mix and gases. The broken line between stations Nos. 5 and 6 gives the probable temperature between these two stations.

The observations indicated that it is impractical to use pyrometers attached to the moving parts of the kiln; but if pyrometers were installed in the dust chamber at the feed end of the kiln and in the hood at the discharge end of the kiln they would be of great assistance in keeping the clinkering zone in the proper place. If the clinkering zone is too far from the discharge end of the kiln, part of the kiln merely acts as a cooler and as for burning clinker, the kiln might have been shorter; and if the clinkering zone is too near the discharge end of the kiln, unburnt clinker may be discharged or the nose ring of the kiln and the hood lining may become damaged, due to excessive heat.

The data obtained by the use of pyrometers at stations Nos. 2 to 6 inclusive does not give reliable results for the reasons mentioned above, but the arrangement of the equipment and results obtained, we believe are original and are given merely as progress in research. These results have not been used in computing heat distribution or making heat balance as described later on in this paper.

Kiln Gas Analyses

Samples of kiln gases were collected, at various times, from the feed end of the kiln (Station No. 1) and analyzed, in an Orsat Hand Analyzer, for carbon dioxide (CO_2) and free oxygen (O_2) and carbon monoxide (CO). The results of the analyses are given in Table 1. It will be noticed that the carbon dioxide varied from 17.5% to 23.2%, and free oxygen from 1% to 5.5%, and carbon monoxide was found only in one sample. This sample contained .1% free oxygen and 1.3% carbon monoxide; and indicates that with only a fraction of 1% of free oxygen the gases may contain carbon monoxide.

Powdered coal can be burned with a small amount of excess air, and unless air is required for purposes other than combustion, excess air should be kept at a minimum. If excess air is necessary, a constant volume, no doubt, should be used, but since the operator cannot tell from physical appearances in the kiln just how much excess air is being admitted, a combustion recorder would be of valuable assistance in maintaining constant conditions in the kiln. It will be shown later that excess air is essential with the present equipment for burning cement clinker.

Table 1—Observations at Station No. 1

Date	Time	Kiln Gases CO_2	O_2	CO	Temp.	Draft
		Per Cent by Volume			Degrees F.	Inches
4-24-16	9:00 A. M.	23.2	0.9	0.0	930	
	10:00	21.2	0.1	1.3	1070	
	11:00	22.8	0.8	0.0	1090	
	1:00 P. M.	18.2	4.1	0.0	1100	
	2:00	20.7	2.8	0.0	1090	
	3:00	20.1	3.2	0.0	1090	
	4:00	19.7	3.0	0.0	1080	
	5:00	21.4	2.7	0.0	1070	
4-25-16	9:00 A. M.	22.0	1.2	0.0	1040	
	10:00	20.6	2.0	0.0	1030	
	11:00	21.2	1.5	0.0	1010	
	1:00 P. M.	20.7	2.6	0.0	1010	
	2:00	22.2	2.4	0.0	1000	
	3:00	22.3	1.7	0.0	1040	
	4:00	20.7	2.8	0.0	1030	
4-26-16	9:00 A. M.	22.0	0.9	0.0	1020	
	10:00	22.5	1.5	0.0	1050	
	11:00	21.8	2.1	0.0	1040	
	1:00 P. M.	22.0	1.4	0.0	1030	
	2:00	21.5	2.1	0.0	1040	
	3:00	20.8	2.2	0.0	1050	
	4:00	19.7	3.0	0.0	1050	
6-16-16	9:30 A. M.	18.9	3.3	0.0	1110	.10
	9:45	17.5	4.6	0.0		.11
	10:25	17.8	4.6	0.0		.11
	10:30	18.3	4.9	0.0	1100	.11
	10:45	17.0	5.0	0.0		.11
	11:00	18.4	4.9	0.0	1080	.11
	11:30	17.9	4.6	0.0	1060	.11
	1:00 P. M.	17.3	5.0	0.0	1090	.13
6-19-16	1:10	18.4	4.9	0.0		.17
	1:30	18.0	4.3	0.0		.20
	2:00	19.0	3.8	0.0		.18
	2:30	17.7	5.0	0.0		.17
	3:00	18.3	4.8	0.0		.20
	4:00	20.1	4.1	0.0		.13
	4:30	19.6	4.8	0.0		.15
	5:00	19.7	4.5	0.0		.15
	5:30	19.5	4.2	0.0		.14
6-20-16	8:30 A. M.	17.4	4.8	0.0		.14
	9:00	18.1	4.3	0.0		.12
	9:30	16.8	4.9	0.0		.16
	10:00	19.2	4.0	0.0		.08
	10:15	20.1	3.4	0.0		.08
	10:30	22.0	1.7	0.0		.02
	10:45	18.8	4.4	0.0		.12
	11:15	19.3	3.8	0.0		.10
	11:30	19.1	4.6	0.0		.08
	1:00 P. M.	17.5	5.5	0.0		.12

Draft

The static draft at the feed end of the kiln (station No. 1) was measured and is also given in Table I. It varied from .02 to .20 in. of water. The amount of draft at any given time is not essential but the variation shows the irregularity in the operation of the kiln.

Changes in the Mix

The thermo-couple tubes at the various stations were removed and samples of the mix were collected from the holes while the kiln was operating under normal conditions. The samples obtained from these points and samples of the mix before entering the kiln and the clinker after being discharged from the kiln were analyzed for water and ignition losses (CO_2). The percentages of water in the mix and ignition losses in the dry mix are shown by the curves in Fig. 13 and Fig. 14. The straight line sections, no doubt, should be connected by curves instead of forming angles at their intersections. The lines were extended to form angles in order to indicate the zones of heat distribution.

KILN GASES

The kiln gases are made up of carbon dioxide liberated from the calcium and magnesium carbonates in the mix, combustion gases and excess air. The carbonates produce 213.7 pounds of carbon dioxide per barrel of clinker. The amount of combustion gases per barrel of clinker depends on the composition of the coal and the amount required per barrel of clinker. The air is indefinite but could be determined by gas analysis or metering the air entering the kiln.

The coal used during the observations was from Neff Mine No. 1 (Ohio) and gave the following ultimate analysis after drying and pulverizing:

Carbon	74.68%
Sulphur	3.52%
Hydrogen	5.07%
Oxygen	6.55%
Nitrogen	1.18%
Ash	9.00%
Total	100.00%

and required 10.29 lbs. of air per pound of coal for "ideal combustion"—forming 11.2 lbs. of combustion gases with the following composition:

Carbon Dioxide (CO_2)	2.74 lbs.
Sulphur Dioxide (SO_2)	.07 "
Steam (H_2O)	.46 "
Nitrogen (N_2)	7.93 "

Neglecting the sulphur dioxide, the dry combustion gases contain 18.06%, by volume, of carbon dioxide.

By combining the carbon dioxide liberated from the carbonates in the mix with the carbon dioxide in the combustion gases the carbon dioxide in the kiln gases may be computed. The curve in Fig. 3 gives the carbon dioxide in the dry kiln gases, per cent by volume, for different amounts of coal per barrel of clinker and "ideal combustion."

It is impractical to operate a rotary kiln of the present type and control the air supply so as to have "ideal combustion;" and since it is more economical to have a slight excess air rather than too little, the air supply should be arranged so as to give free oxygen in the kiln gases, rather than carbon monoxide.

By the use of the curves in Fig. 4, the approximate rate which the coal is being consumed per barrel of clinker could be determined from an analysis of the kiln gases, that is, percentages of carbon dioxide, oxygen and carbon monoxide in the dry kiln gases. If this method is used for checking the amount of coal being consumed per barrel of clinker, the curves must be computed from an ultimate analysis of the coal being used and the kiln should be run several minutes without stopping or making any changes before collecting the gas sample. The following examples will explain the use of the curves:

(a) Assume that an analysis of the kiln gases gave 24% of carbon dioxide and 2.5% of oxygen. Follow along the horizontal line to 24% of carbon dioxide, then vertically to 2.5% oxygen. Interpolate between the adjacent coal lines and the point (24% CO_2, 2.5% O) gives approximately 112 lbs. of coal per barrel of clinker.

(b) Assume that an analysis of the kiln gases gave 26.5% of carbon dioxide, 1% of carbon monoxide and .5% of oxygen. Follow along the horizontal line to 26.5% of carbon dioxide, then vertically to 1% of carbon monoxide, then follow an imaginary coal line through the point (26.5% CO_2, 1% CO) to 0 (zero) carbon monoxide and then vertically to .5% of oxygen. Interpolate between the adjacent coal lines and the point 26.5% CO_2, 1% CO, .5% O) gives approximately 110 lbs. of coal per barrel of clinker.

If, under (a), the gases had contained carbon monoxide instead of oxygen, the amount of coal per barrel of clinker would have been determined the same way except that the point would have been located in the carbon monoxide section of the curves instead of in the oxygen section.

The observations indicated that it is sometimes necessary to admit additional air to the kiln or reduce the speed of the kiln—reducing the rate of travel of the mix through the kiln—although all the combustible in the coal is being consumed. There appears to be a certain clinker capacity for a given kiln under which conditions become balanced. If the capacity is reduced below this rate, the clinkering zone will travel back into the kiln; but if the capacity is increased beyond this rate, the clinkering zone will travel nearer the discharge end of the kiln. In the latter case, increasing the kiln coal does not have much effect except to raise the temperature of the combustion zone, increase radiation and perhaps burn the kiln lining. The trouble is; the kiln has become unbalanced—giving too much heat in the clinkering zone and not enough in the heating and decomposition zones. Under these conditions, excess air admitted to the kiln would carry the excess heat from the clinkering zone to the heating and decomposition zones and stabilize conditions. If too much excess air were admitted to the kiln, too much heat would be carried from the clinkering zone to the heating and decomposition zones, unbalancing conditions and causing the clinkering zone to travel back into the kiln. Combustion gases, formed by the coal which supplies the heat radiated from the kiln shell surrounding the combustion zone, act the same as excess air in stabilizing conditions. Excess air would be more economical because it requires only about 75% of the coal to raise its temperature to that of the combustion zone as would be required to form combustion gases with equal heat carrying capacity. The difference represents the heat lost by radiation on account of excessive temperature and this excessive temperature also causes the reduction in the thickness of the kiln lining. If kiln operators would *admit excess air* instead of *forcing the fire*, kiln linings would last longer and less heat would be lost by radiation.

The most economical capacity of a given kiln would have to be determined by experiment and the total cost of production; and when established, the operator would find it necessary to use excess air to keep the kiln lining from overheating and wearing rapidly. Just how much excess air should be used and just how much is being used at any given time is beyond the ability of any operator to judge from physical appearances in the kiln. In such cases it would be necessary to use combustion recorders with carbon dioxide, oxygen and carbon monoxide attachments. It would not be necessary to record the percentages of the three gases continuously. The percentage of free oxygen in the dry kiln gases is of prime importance because it gives the amount of excess air admitted to the kiln; and if the recorder could be thrown on to the carbon dioxide and carbon monoxide attachments at intervals, the instrument would be of great assistance to the operator. The practical use of such instruments is feasible and is recommended.

TEMPERATURE OF THE MIX

From the curves, Fig. 13 and Fig. 14, which give the percentages of water in the mix and ignition losses in the dry mix, the temperature of the mix for any point in the kiln may be obtained. The mix enters the kiln at 70° F. and is raised to 212° F. by the time it has traveled 4 ft. into the kiln—point where the water begins to evaporate. It remains at this temperature until all of the water has been driven off—47.5 ft. from the feed end of the kiln—when the temperature begins to rise, reaching 1650° F. by the time it has traveled 58.5 ft. into the kiln—point where the carbonates begin to decompose. It remains at 1650° F. until all the carbonates have been decomposed—81.5 feet from the feed end of the kiln—when the temperature begins to rise, reaching 2700° F., clinkers and then cools to 2160° F. by the time it has been discharged from the kiln. Curves giving the approximate temperature of the mix are shown in Fig. 13 and Fig 14.

DATA

The following data were observed, assumed or computed for use in making the heat distributions and heat balances:

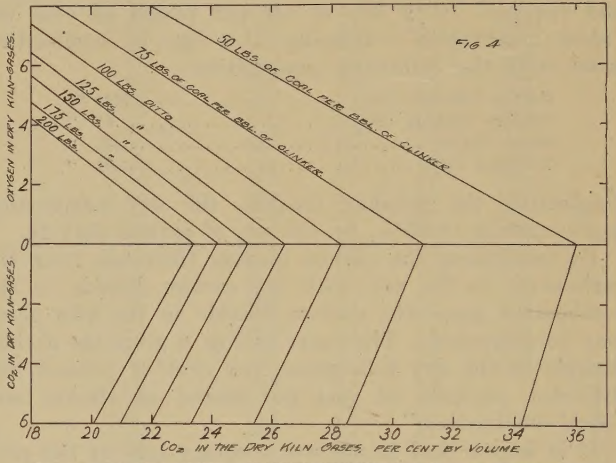
Dry raw mix per barrel of clinker, lbs.	600
Water in the slurry, per cent	45.6
Slurry per barrel of clinker, lbs	1,103
Water in the slurry per barrel of clinker, lbs	503
Clinker per barrel, lbs.	376
Clinker per kiln hour, bbls	20
$CaCO_3$ in the dry raw mix, per cent	75
$CaCO_3$ in the dry raw mix, per barrel of clinker, lbs	450
$MgCO_3$ in the dry raw mix, per cent	5
$MgCO_3$ in the dry raw mix, per barrel of clinker. lbs	30
Heat required to decompose 1 lb. of $CaCO_3$, B. T. U	584
Heat required to decompose 1 lb. of $MgCO_3$, B. T. U	384
CO_2 liberated from the Carbonates per barrel of clinker, lbs	213.7
Temperatures, Degrees Fahr.:	
Slurry entering the kiln	70
Air entering the kiln	70
Coal entering the kiln	70
Decomposition of the carbonates	1,650
Combustion zone	3,000
Clinkering	2,700
Clinker leaving the kiln	2,160
Gases leaving the kiln:	
Wet Process, actual	1,100
Wet Process, theoretical	750
Dry Process, actual	1,500
Gases leaving the decomposition zone:	
Wet Process, observed conditions	2,555
Wet Process, theoretical conditions	2,660
Dry Process, theoretical conditions	2,180
Specific Heats:	
Carbon dioxide	$.1900 + .00012t$
Superheated steam	.463
Dry raw mix	.206
Unburnt clinker	.180
Clinker	.246
Combustion gases	$.2364 + .0000476t$
Air	$.2336 + .0000232t$
Heat per lb. of coal as fired, B. T. U	13,160
Combustion gases per lb. of coal, lbs	11.2
Heat available per lb. of coal with the combustion gases at 750° F., B. T. U. $= 13{,}160 - 11.2 \times .250 \times (750 - 70) =$	11,250
Heat available per lb. of coal with the combustion gases at 1,100° F., B. T. U., $= 13{,}160 - 11.2 \times .263 \times (1{,}100 - 70) =$	10,130
Heat available per lb. of coal with the combustion gases at 1,500° F., B. T. U., $= 13{,}160 - 11.2 \times .273 \times (1{,}500 - 70) =$	8,790
Heat available per lb. of coal with the combustion gases at 3,000° F., B. T. U., $= 13{,}160 - 11.2 \times .309 \times (3{,}000 - 70) =$	3,030
Heat required to vaporize 1 lb. of water and raise the steam to 750° F., B. T. U., $= 970.4 + 142 + .463 \times (750 - 212) =$	1361.5
Heat required to vaporize 1 lb. of water and raise the steam to 1,100° F., B. T. U., $= 970.4 + 142 + .463 \times (1100 - 212) =$	1527.5
Excess air per bbl. of clinker, lbs	300

HEAT REQUIREMENTS

The following computations give the heat requirements per barrel of clinker for each change in the mix:

Heat required to vaporize the water in the slurry and raise the steam to 750° F., B. T. U., $= 503 \times 1{,}361.5 =$		684,755
Heat required to vaporize the water in the slurry and raise the steam to 1,100° F., B. T. U., $= 503 \times 1{,}527.5 =$		765,000
Heat required to raise the dry mix from 70° F. to 1,650° F., B. T. U., $= 600 \times .206 \times (1{,}650 - 70) =$		195,000
Heat required to decompose the carbonates, B. T. U.:		
$CaCO_3 = 450 \times 784 =$	352,320	
$MgCO_3 = 30 \times 384 =$	11,520	364,320
Heat required to raise the CO_2, liberated from the carbonates, from 1,650° F. to 3,000° F., B. T. U., $= 213.7 \times .4606 \times (3{,}000 - 1{,}650) =$		133,000
Heat required to raise the CO_2, liberated from the carbonates, from 1,650° F. to 2,555° F., B. T. U., $= 213.7 \times .4420 \times (2{,}555 - 1{,}650) =$		85,500
Heat required to raise the CO_2, liberated from the carbonates, from 1,650° F. to 2,660° F., B. T. U., $= 213.7 \times .450 \times (2{,}660 - 1{,}650) =$		97,000
Heat required to raise the CO_2, liberated from the carbonates, from 1,650° F. to 2,180° F., B. T. U., $= 213.7 \times .421 \times (2{,}180 - 1{,}650) =$		47,600
Heat required to raise the excess air from 70° F. to 3,000° F., B. T. U., $= 300 \times .268 \times (3{,}000 - 70) =$		235,000
Heat radiated from the kiln shell and hood, B. T. U.:		
From the combustion zone	64,600	
From the heating zone	75,400	140,000
Heat recovered from the clinker in cooling from 2,700° F. to 2,160° F., B. T. U., $= 376 \times .246 \times (2{,}700 - 2{,}160) =$		50,000
Heat recovered from the CO_2, liberated from the carbonates, in cooling from 2,555° F. to 1,100° F., B. T. U., $= 213.7 \times .408 \times (2{,}555 - 1{,}100) =$		126,800
Heat recovered from the CO_2, liberated from the carbonates, in cooling from 2,660° F. to 750° F., B. T. U., $= 213.7 \times .374 \times (2{,}660 - 750) =$		152,700
Heat recovered from the CO_2, liberated from the carbonates, in cooling from 2,180° F. to 1,500° F., B. T. U., $= 213.7 \times .421 \times (2{,}180 - 1{,}500) =$		59,900
Heat recovered from the excess air in cooling from 3,000° F. to 1,100° F., B. T. U., $= 300 \times .280 \times (3{,}000 - 1{,}100) =$		156,000

The above quantities were computed for specific cases; but by using the proper variables, curves could be developed to cover the heat requirements for any case. The proper quantities could then be obtained from the curves for making a heat distribution and heat balance for any given case.



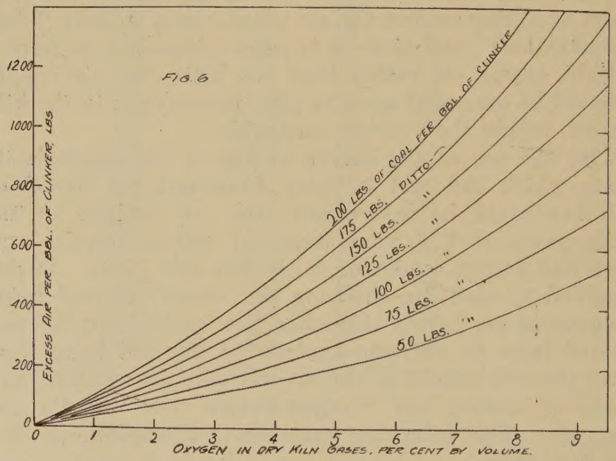


FIG. 4—CURVES GIVING THE KILN COAL PER BARREL OF CLINKER FOR VARIOUS PERCENTAGES, BY VOLUME, OF CARBON DIOXIDE AND OXYGEN OF CARBON MONOXIDE IN THE DRY KILN GASES

FIG. 6—CURVES GIVING THE EXCESS AIR IN KILN GASES PER BARREL OF CLINKER FOR VARIOUS PERCENTAGES OF OXYGEN IN THE DRY KILN GASES

The curves in Fig. 5 give the heat required per barrel of clinker to heat and vaporize the water in the slurry and superheat the steam formed to the temperature of the gases leaving the kiln for different percentages of

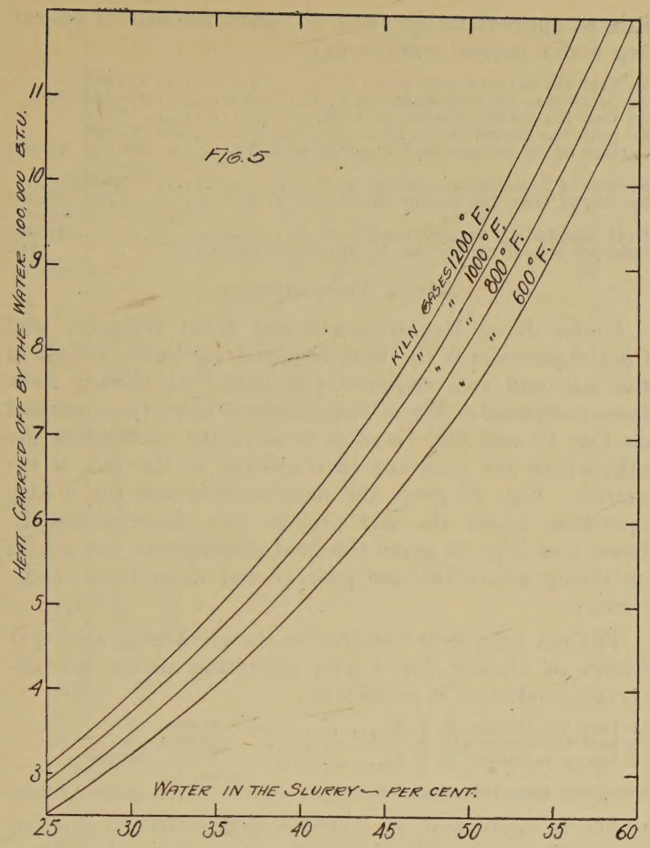


FIG. 5—CURVES GIVING THE HEAT CARRIED OFF BY THE WATER IN THE SLURRY PER BARREL OF CLINKER

water in the slurry and temperatures of the gases leaving the kiln.

The curves in Fig. 6 give the excess air per barrel of clinker for different percentages of free oxygen in the dry kiln gases and amounts of coal per barrel of clinker; and the curves in Fig. 7 give the heat carried off by the excess air per barrel of clinker for different amounts of excess air per barrel of clinker and temperatures of the gases leaving the kiln.

The curves in Fig. 8 give the heat loss, B.T.U., per barrel of clinker on account of carbon monoxide in the kiln gases for different percentages of carbon monoxide in the dry kiln gases and amounts of coal per barrel of clinker; and the curves in Fig. 9 give heat loss per cent, on account of carbon monoxide in the kiln gas for different percentages of carbon monoxide in the dry kiln gases and amounts of coal per barrel of clinker.

The curve in Fig. 10 gives the heat carried off by the carbon dioxide, liberated from the carbonates, per barrel of clinker for different temperatures of the gases leaving the kiln.

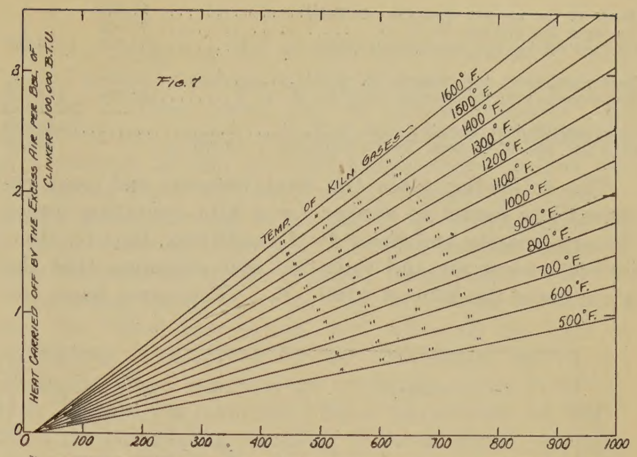
The curves in Fig. 11 give the heat carried off by the combustion gases and the heat available for work per lb. of coal for different temperatures of the combustion gases.

The curve in Fig. 12, gives the maximum temperature of the combustion gases for different percentages of carbon dioxide in the dry combustion gases when all the heat of combustion is absorbed by the combustion gases or by the combustion gases and excess air.

HEAT BALANCES AND COAL REQUIREMENTS

The following gives the heat balance and coal required per barrel of clinker under the observed conditions:

Heat carried off by the water, B. T. U.	765,000	
To heat the dry raw mix, B. T. U.	195,000	
To decompose the carbonates, B. T. U.	364,320	
To heat the carbon dioxide, B. T. U.	85,500	
To burn the clinker, B. T. U.	71,000	
To heat the excess air, B. T. U.	235,000	
To supply radiation, B. T. U.	140,000	
Carried off by the combustion gases, B. T. U.	455,580	2,311,400
Recovered from the clinker, B. T. U.	50,000	
Recovered from the carbon dioxide, B. T. U.	126,800	
Recovered from the excess air, B. T. U.	156,000	323,800
Heat supplied by burning coal, B. T. U.		1,978,600
Coal, per bbl. of clinker, lbs. = 1,978,600 ÷ 13,160 =		150.35



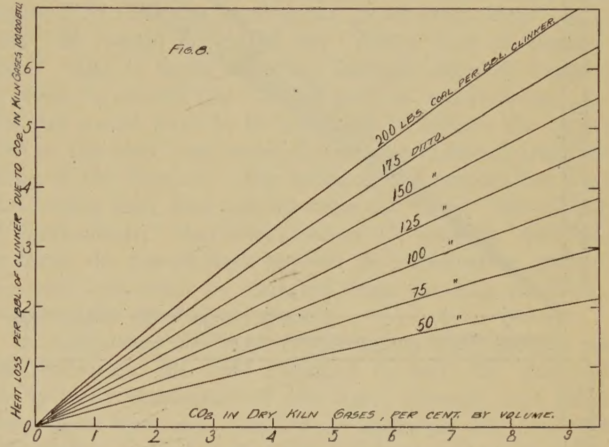


FIG. 7—CURVES GIVING THE HEAT CARRIED OFF BY THE EXCESS AIR IN THE KILN GASES PER BARREL OF CLINKER FOR DIFFERENT AMOUNTS OF EXCESS AIR PER BARREL OF CLINKER AND TEMPERATURE OF THE GASES LEAVING THE KILN

FIG. 8—CURVES GIVING THE HEAT LOSS PER BARREL OF CLINKER DUE TO CARBON MONOXIDE IN THE KILN GASES FOR DIFFERENT PERCENTAGES OF CARBON MONOXIDE IN THE DRY KILN GASES, AND AMOUNTS OF COAL PER BARREL OF CLINKER

The coal consumption during the period covering the observations was approximately 160 lbs. per barrel of clinker. Therefore considering the moisture in the coal as received and the varying quality in a month's supply, the heat balance appears approximately correct. Two of the divisions of the heat balance might be questioned, namely: *Heat recovered from the clinker* and *Heat radiated*. It would be rather difficult to determine the exact amount of either, especially with the instruments available in a cement plant; but a large error in the former would not affect the final results materially and the latter was practically determined by differences, that is, the other divisions were computed and then knowing that about 150 lbs. of dry coal were consumed per barrel of clinker, heat not otherwise accounted for was assumed to be radiated.

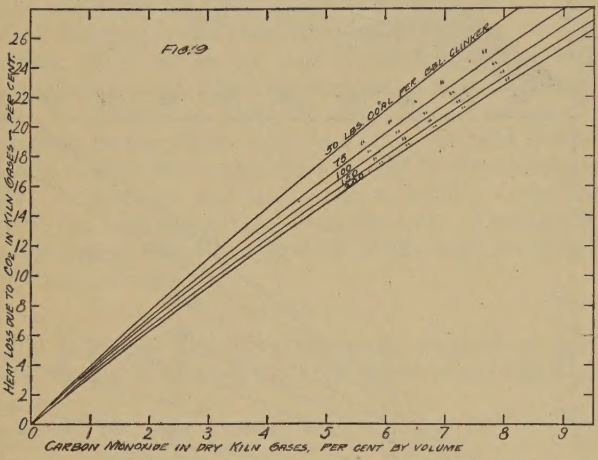
The following gives the heat balance and coal required per barrel of clinker for a kiln operating under the *wet process* and theoretical conditions, that is, eliminating excess air and radiation and assuming that the gases leave the kiln at 750° F.:

Heat carried off by the water, B. T. U.	684,755
To heat the dry raw mix, B. T. U.	195,000
To decompose the carbonates, B. T. U.	364,320

To heat the carbon dioxide, B. T. U.	97,000	
To burn the clinker, B. T. U.	71,000	
Carried off by the combustion gases, B. T. U.	204,055	1,616,130
Recovered from the clinker, B. T. U.	50,000	
Recovered from the carbon dioxide, B. T. U.	160,250	210,250
Heat supplied by burning coal, B. T. U.		1,405,880
Coal per bbl. of clinker, lbs. = 1,405,880 ÷ 13,160 =		106.83

The following gives the heat balance and coal required per barrel of clinker for a kiln operating under the *dry process* and theoretical conditions, that is, eliminating excess air and radiation and assuming that the gases leave the kiln at 1500° F. (The gases leave the kiln at approximately 1500° F. when the kiln is operating under normal conditions):

To heat the dry raw mix, B. T. U.	195,000	
To decompose the carbonates, B. T. U.	364,320	
To heat the carbon dioxide, B. T. U.	47,600	
To burn the clinker, B. T. U.	71,000	
Carried off by the combustion gases, B. T. U.	282,400	960,320
Recovered from the clinker, B. T. U.	50,000	
Recovered from the carbon dioxide, B. T. U.	59,900	109,900
Heat supplied by burning coal, B. T. U.		850,420
Coal per bbl. of clinker, lbs. = 850,420 ÷ 13,160 =		64.2



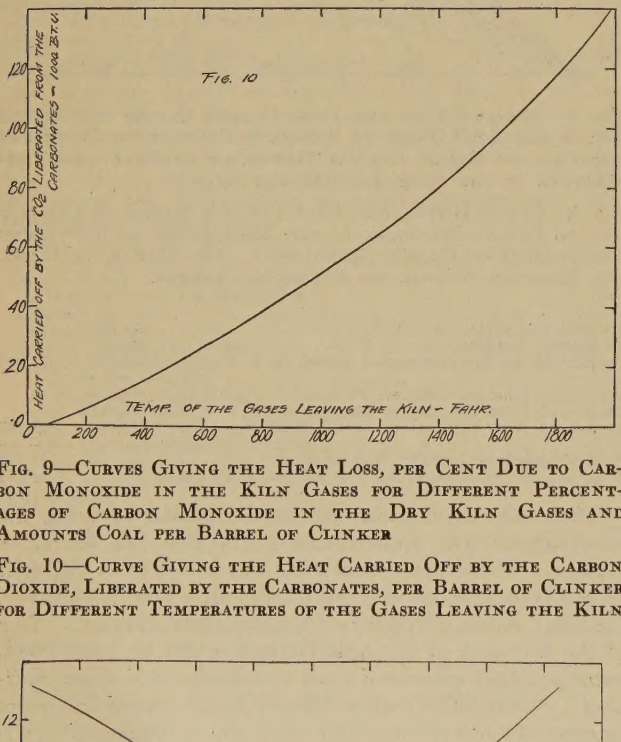


FIG. 9—CURVES GIVING THE HEAT LOSS, PER CENT DUE TO CARBON MONOXIDE IN THE KILN GASES FOR DIFFERENT PERCENTAGES OF CARBON MONOXIDE IN THE DRY KILN GASES AND AMOUNTS COAL PER BARREL OF CLINKER

FIG. 10—CURVE GIVING THE HEAT CARRIED OFF BY THE CARBON DIOXIDE, LIBERATED BY THE CARBONATES, PER BARREL OF CLINKER FOR DIFFERENT TEMPERATURES OF THE GASES LEAVING THE KILN

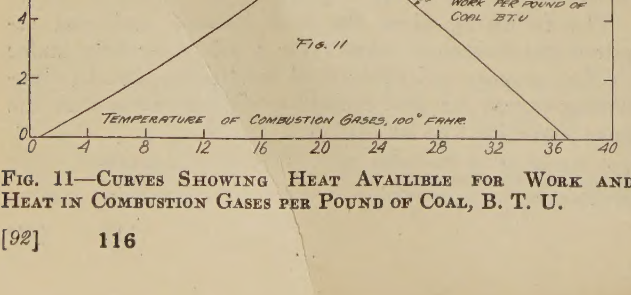


FIG. 11—CURVES SHOWING HEAT AVAILIBLE FOR WORK AND HEAT IN COMBUSTION GASES PER POUND OF COAL, B. T. U.

HEAT DISTRIBUTION

Under *Heat Requirements* and *Heat Balances and Coal requirements* the heat required for each change in the mix and coal required per barrel of clinker have been computed. These requirements have been plotted on Fig. 13 and Fig. 14 so as to show the sections of the kiln where the heat for each change in the mix is required. Fig. 13 gives the heat distribution for a kiln operating under the *wet process* and observed conditions, and Fig. 14 gives the heat distribution for a kiln operating under the *wet process* and theoretical conditions.

The net total heat required in the clinkering zone per barrel of clinker for a kiln operating under the observed conditions is as follows:

To burn the clinker, B. T. U.	71,000	
To heat the excess air, B. T. U.	235,000	
To supply radiation, B. T. U.	57,000	363,000
Recovered from the clinker, B. T. U.	50,000	313,000

which is equivalent to 313000÷3030=103.30 lbs. of coal. This indicates that of the 150.35 lbs. of coal required per barrel of clinker, 103.30 lbs. would be burned in the clinkering zone and 150.35—103.30=47.05 lbs. burned in the decomposition zone. Assume that the carbon dioxide, liberated from the carbonates, was heated to the temperature of the combustion zone, 3000° F., then the heat required in the decomposition zone would be as follows:

To decompose the carbonates, B. T. U.	364,320	
To heat the carbon dioxide, B. T. U.	133,000	
To supply radiation, B. T. U.	33,000	530,320

The 47.05 lbs. of coal which were burned in the decomposition zone has 47.05×3030=142560 B.T.U. available for work; therefore, 142560÷530320=23% of the work in the decomposition zone was done by direct heat of combustion. The clinkering zone is 18.5 ft. long and the decomposition zone is 23 ft. long; therefore, the combustion zone is 18.5+23×.23=23.79 ft. long.

Referring to the heat requirements, it will be noticed that under the observed conditions, the only items in which savings are possible are those affecting radiation, excess air, and temperature of the gases leaving the kiln. Radiation has been divided into two parts, namely; 64600 B.T.U. radiated from the combustion zone and 75400 B.T.U. radiated beyond the combustion zone. The heat radiated from the combustion zone is supplied by burning 64600÷3030=21.32 lbs. of coal; and the heat radiated from the section of the kiln beyond the combustion zone is supplied from the sensible heat of the combustion gases formed by burning the 21.32 lbs. of coal. The heat available in the combustion gases is 21.32×11.2×.331×(3000—1100)=150250 B.T.U., but only 75400 B.T.U. are required for radiation; therefore, 150250—75400 = 74850 B. T. U. are available for work.

The excess air takes up 235,000 B.T.U. in the combustion zone which requires 23500÷3030=77.55 lbs. of coal, producing 77.55×11.2=868 lbs. of combustion gases. The available heat in the excess air and the combustion gases formed by burning the 77.55 lbs. of

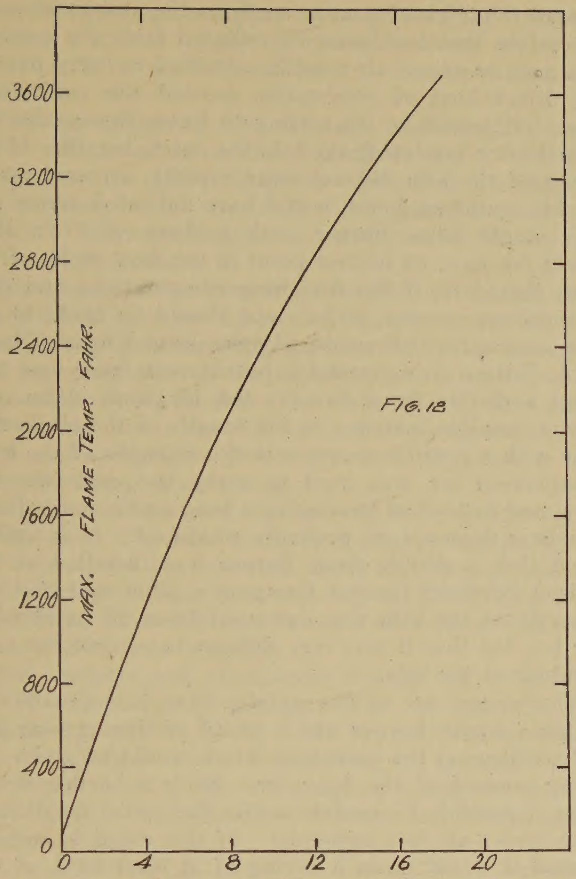


Fig. 12—Curve Giving the Maximum Flame Temperature for Different Percentages of Carbon Dioxide in the Dry Combustion Gases

coal for work beyond the combustion zone is (300×.280+868×.331)×(3000—1100)=443000 B.T.U.

Referring to the two preceding paragraphs, it will be noticed that 21.32 lbs. of coal per barrel of clinker are required to supply the heat radiated from the combustion zone and 77.55 lbs. of coal per barrel of clinker are required to heat the excess air. This coal contains 13160 ×(21.32+77.55)=1300000 B.T.U., but only 74850+443000=517850 B.T.U. are available for useful work.

If excess air and radiation were eliminated and the gases leave the kiln at 750° F., it would require 106.83 lbs. of coal per barrel of clinker. Of this amount, (71000—50000)÷3030=6.93 lbs. would be burned in the clinkering zone and 106.83—6.93=99.90 lbs. in the decomposition zone. Assume that the carbon dioxide, liberated from the carbonates, is heated to the temperature of the combustion zone, 3000° F., then 364320+133000=497320 B.T.U. would be required in the decomposition zone. The 99.90 lbs. of coal contain 302697 B.T.U. available for useful work; therefore, 303697÷497320=60.8% of the work in the decomposition zone would be done by direct heat of combustion. The clinkering zone is 18.5 ft. long and the decomposition zone is 23 ft. long; therefore, the combustion zone would be 18.5+23×.608=32.5 ft. long. It would probably be impractical to burn clinker with a flame 32.5 feet long; therefore, it would be necessary to shorten the flame, burn more coal and either radiate the direct heat of combustion or admit excess air to carry the direct heat of combustion beyond the combustion zone. Excess air would be more economical.

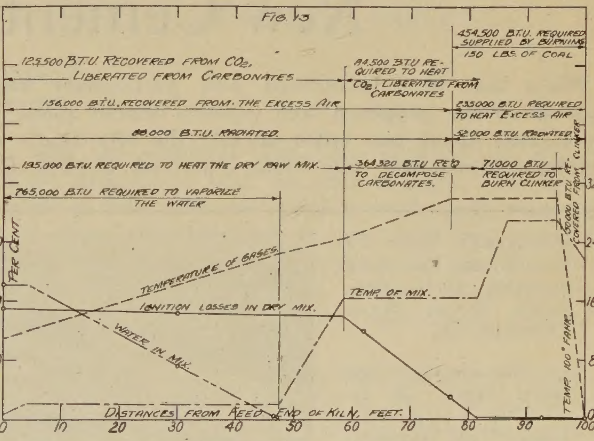
The gas temperature curves in Figs. 13 and 14 were computed from heat balances for the sections of the kiln where changes in the temperatures are indicated; and have no relation to the temperature curve obtained by the pyrometers.

Discussion

In the foregoing the terms "ideal combustion" and "direct heat of combustion" have been used freely. The meaning of these terms may be rather indefinite. In the use of the former, reference is made to the burning of a mixture of coal and air, proportioned so that the combustion gases will not contain either free oxygen or carbon monoxide; and in the use of the latter, reference is made to the heat available after the combustion gases have been heated to the required temperature.

Referring to the curve in Fig. 12, it will be noticed that for "ideal combustion" and when all the heat of combustion is absorbed by the combustion gases, the maximum flame temperature would be about 3700° F. If it is desired to maintain a flame temperature of 3000° F. in the combustion chamber, the heat which would be required to raise the combustion gases from 3000° F. to 3700° F. would be called the "direct heat of combustion." And if there were not enough external work to be done to absorb the "direct heat of combustion," excess air would have to be admitted to absorb the excess heat or the said heat would have to be radiated from the walls of the furnace. The work in the combustion zone of a rotary kiln does not consume all of the "direct heat of combustion;" therefore, excess air must be admitted to carry the excess heat beyond the combustion zone of the said heat must be radiated from the kiln shell surrounding the combustion zone.

In computing the heat requirements and making the heat balances, the heat required to melt the mix and the heat of formation of the lime, alumina and silica compounds were not considered; and since the available information indicates that the latter is greater than the former and they are of opposite signs, it might be advisable to exclude them from consideration until physicists have determined the exact value of each. In fact,



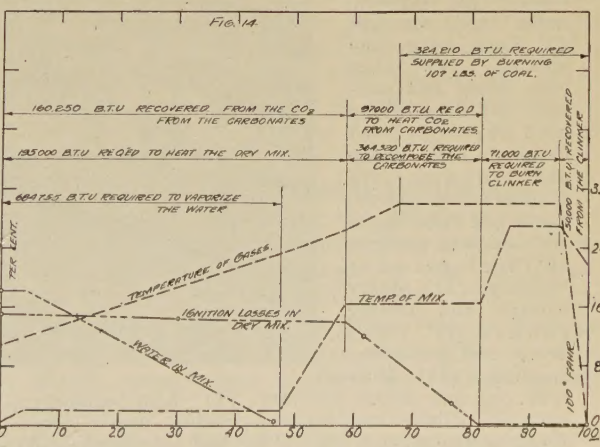


Fig. 13

Fig. 14

the statement that the mix melts might be questioned since alumina melts at 3722° F. and silica melts at 3452° F., but the mixture of lime, alumina and silica might melt at a lower temperature than either on the same principle that salt mixed with ice lowers the melting point of the ice. If the heat of formation is greater than the heat required to melt the mix, excess air would have to be admitted to carry the excess heat beyond the combustion zone, or the excess heat would have to be radiated from the kiln shell surrounding the clinkering zone.

It will be noticed from the foregoing, that a short flame, in the "wet process" does not distribute the heat where required without radiating part of the direct heat of combustion or admitting excess air to carry the heat which would be radiated from the kiln shell beyond the combustion zone. Radiation and excess air lowers the efficiency of the kiln; therefore, the kiln should be insulated against radiation, excess air should be eliminated and the burner should produce a long flame and at the same time give the highest temperature in the clinkering zone.

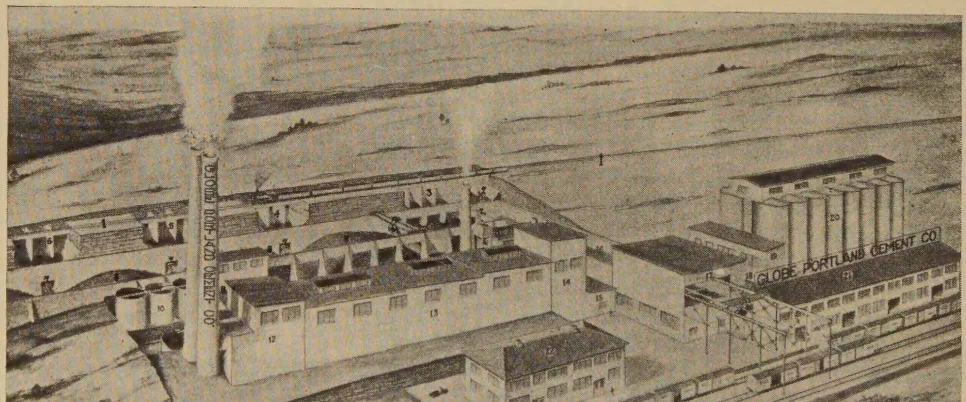
The writers were informed, by a representative of a manufacturer of insulating materials, that one of the large cement companies had placed two orders with his company for materials to insulate kilns. At the time of placing the first order, it was proposed to insulate the section of the kiln beyond the clinkering zone only; but at the time of placing the second order, it was proposed to insulate the kiln the entire length. The main difficulty in insulating kilns has been the lack of satisfactory materials; but the fact that the purchaser placed a repeat order indicates that satisfactory materials may be available. The fact that the kiln was not insulated around the clinkering zone confirms the statement made heretofore that heat must be radiated from the combustion zone or excess air must be admitted to carry part of the direct heat of combustion beyond the combustion zone. It would be interesting to know the results obtained after insulating the kiln the entire length. If the lining of the kiln did not wear rapidly, an analysis of the kiln gases no doubt, would have indicated excess air.

A single flame burner with a flame 32.5 ft. long would not have its hottest point in the first 20 ft. of the kiln; therefore, if the foregoing computations and conclusions are correct, an attempt should be made to design a burner which would give the desired flame. Thomas A. Edison was granted a patent some time ago covering a double flame burner; but his main claim covered a possible increase in the length of the clinkering zone with a possible increase in the capacity of the kiln. Compressed air was used to carry the coal into the kiln; and instead of producing a long and a short flame, two long flames were probably produced. It is understood that a double flame burner was installed at the Edison Portland Cement Company's plant and that the capacity of the kiln was increased from 27 to 42 bbls. per hr., but that it was very difficult to control the temperature of the kiln.

The writers are of the opinion that it is possible to design a double burner which would produce a long and a short flame at the same time which would be under absolute control of the operator. Such a burner would make it possible to insulate a kiln the entire length and keep excess air to a minimum. If this could be accomplished it would mean a saving of at least 25% of the coal now being used for burning cement clinker—reducing the cost of cement and conserving the coal supply.

New Cement Plant for Iowa

Plans have been completed and preliminary work started on the proposed wet process cement plant to be erected about two miles outside the city limits of Dubuque, Iowa, for the Globe Portland Cement Co. Lime rock and shale will be used as the principal raw materials. An ample supply of high quality materials are to be found in the vicinity, and transportation facilities are good. Information has been submitted to


GLOBE PORTLAND CEMENT CO.

Engineer's View of the Globe Portland Cement Co.'s Proposed Plant Near Dubuque, Ia.

(1) Incoming raw material track, 70 ft. above outgoing tracks; (2) Gypsum dump and storage; (3) Coal dump and storage; (4) Lime rock dump and storage; (5) Shale dump and storage; (6) Crushed rock dump and storage; (7) Crushers and pulverizers; (8) Raw material and coal storage; (9) Wet grinder building; (10) Slurry storage and mixing tanks; (11) Coal dryer and pulvreizer building; (12) Dust collecting and potash recovery; (13) Kiln building; (14) Burner building; (15) Clinker coolers; (16) Clinker storage; (17) Clinker hoppers over grinders, gravity feed; (19) Air separator building; (20) Cement storage tanks; (21) Bagging department; (22) Office and laboratory; (23) Dock on Mississippi river; (24) Cement loading tracks; (25) Main line C., M. & St. P. Ry.

the officials of the company by engineers and chemists showing that the supply of materials from which the cement will be made is sufficient to last for about 100 years.

The convenience of four railroads and the Mississippi River will mean an economical advantage to the new company when actual shipping operations are started. The territory which the Globe Co. expects to serve will include Wisconsin, Mincnsota, northwestern Illinois and northeastern Iowa.

The plant will be located on the side of a bluff sloping to the Mississippi River, and the gravity system will be used largely in handling the material. Raw materials will be brought in on the supply track at an elevation approximately 70 ft. above the main tracks. The dump and storage reservoirs will be located along the supply track and the gravity power system is expected to add to the economy of operating.

A gypsum dump and storage will have a capacity of 2,000 tons. The coal dump and storage a capacity of 2,500 tons, and the lime rock dump and storage and the shale storage will have a capacity of 2,000 tons each. In addition there will be a crushed rock dump and storage of 2,000 tons capacity.

The crushers and pulverizers will be fed by gravity and will discharge by gravity. The raw material and coal storage will be 70 ft. x 480 ft., and will be served by a traveling crane for distributing the material. The building containing the wet grinding equipment will be 66 ft. x 88 ft., and the slurry storage and mixing tanks will have the capacity of 6,000 bbls.

Dust collecting and potash recovery equipment will be located at the end of the shale building, the main kiln building being 44 ft. x 260 ft. From the kilns the clinker will pass to the clinker coolers, having a gravity discharge, and then be transferred to a clinker storage 60 ft. x 270 ft. Clinker hoppers will be built over the grinding equipment so as to feed the machines by gravity. Between the clinker grinders and the cement storage tanks an air separator building is provided for, and a battery of silo tanks will provide a storage for 250,000 bbls. of the finished product.

Between the storage tanks and the cement loading tracks the bagging will be done in a building 40 ft. x 180 ft., with four shipping exits.

The officers of the Globe Portland Cement Co., incorporated under the laws of the state of Minnesota with a capital of $5,000,000, are:

J. L. Neddersen, president, Minneapolis, Minn.; F. P. O'Malley, treasurer, St. Paul, Minn.; H. L. Johnson, secretary, Des Moines, Ia.; F. M. Miner, vice-president and counsel, Minneapolis, Minn.

Other directors of the company are: D. A. Wallace, St. Paul, Minn.; O. H. Diercks, St. Paul, Minn.; R. M. Johnson, Minneapolis, Minn.; Leo F. Jaeger, Dubuque, Iowa.

Executive offices are at 416-18 McKnight Bldg., Minneapolis, Minn. Plans for the plant were prepared by Charles L. Phillsbury Co., engineers, Minneapolis and St. Paul.

Segregation

As It Applies to Tanks as Segregating or Mixing Devices

By Charles Catlett
Chemist and Geologist

> The following article sets forth the results of some original investigations of a chemist engaged by the author and whose time was given exclusively to the making of continuous experiments in connection with segregation, more especially as it is a factor in the manufacture of portland cement.
>
> The author found, when his attention was called to the question, that practically no data was available on the subject, although it is believed that the question of segregation is probably among the most important ones before the manufacturers of portland cement. This paper is, no doubt, the start of a most valuable line of investigations.—Editors.

When solids, in a greater or less state of subdivision, are agitated together in such manner that the particles have some freedom of movement, there is a tendency towards mixing or uniformity up to a certain point, depending on many factors, and if, momentarily, or in parts of the mass, a more perfect mixture should exist, the tendency is again towards segregation or separation. This also depends upon many factors. Apparently the principal features affecting segregation are size, specific gravity, shape and character of the surface of the particles. One of these factors may tend to carry a particle in one direction, and another in the opposite direction, and the resultant may be a tendency to remain in close association with its surroundings. The tendency is for those particles which have the same resultant of the above characteristics to come together, and that means a segregation from, or separation from, the other particles. This tendency is an obstacle to uniformity, and, when such may be obtained, immediately proceeds to destroy it.

As uniformity is the most essential factor in all operations in which material may be in any way mixed together, such limited study as I have given to the subject leads me to think that no more important question can be brought before engineers and manufacturers, and I do so in the hope that others more worthy may devise methodfs for exorcising this evil spirit of segregation and for freeing us in part at least from its malign influence.

The characteristics which seem to have the most influence in producing segregation are physical, and have nothing to do with chemical composition, so that if large and small particles have the same, or very similar analyses, a mixture may segregate greatly and yet the parts may show very little variation from a chemical standpoint. But usually materials which differ in shape, size, specific gravity and surface also differ greatly chemically.

In the hope of finding at least some general rules or laws bearing on the subject, materials were taken which could be handled easily and which gave good promise of disclosing definite tendencies, and the tests referred to in this paper which have been carried on for several months have been confined entirely to two sizes of sand, though they have been supplemented by parallel tests on other materials. One sand was that used in cement testing with white well rounded smooth grains, passing through a 20-mesh sieve and retained on a 30-mesh sieve. The other was ordinary brown building sand, passing 40-mesh and retained on 60-mesh. The diameter of the brown sand might, roughly, be considered as half of the diameter of the white, and the volume of each brown particle might be considered as approximately one-eighth of a white particle, and in the same weight of the two, there were eight times as many brown particles as white particles. Loosely packed, the brown sand occupied about 14% more space than the white sand.

Preliminary experiments showed that it was practically impossible to get an uniform mixture with such material in any proportions. Or, it was impossible to get a mixture in which any one-tenth or one-twentieth part of the whole might be expected to agree closely with any other one-tenth or one-twentieth part. The most perfect mixture which was gotten was obtained by filling a small glass tank (made from a bottle 8 in. high and 3½ in. in diameter), with very thin alternate layers of brown and white sand, the amounts being weighed and carefully distributed as well as possible over the entire surface. As close a mixture as possible having been obtained in this way, it then seemed desirable to find out how complete a separation could be made by agitating, pouring and dry panning.

In carrying out these preliminary tests a mixture of the sand was first made in the proportion of 85% by weight of the larger sand and 15% of the smaller sand. This was separated by rolling and panning until 55% of the whole was withdrawn from the mixture; which 55% consisted of 99.2% of the large and only .8% of the small sand. The balance (45% of the whole) consisted of 67.5% of large and 32.5% of small sand. Or it is possible, under these conditions, to withdraw a large amount of the total mixture (more than one-half) consisting of the larger sand practically free from small sand. What is left is of course not uniform; but apparently no further complete separation could be brought about by these means. This test was repeated many times, and always with similar, but in no case closely coordinate, results.

Tests were also made with a mixture containing 85% of the fine sand and 15% of the coarse. It was found that it was practically impossible to get any considerable sample of fine sand free from the coarse sand. The action in this case is different from what it is when the coarse sand is in excess, but it was possible to withdraw 31% of the whole, of which 60% was small and 40% was large; and there was left 69% of the whole, of which 96% was small and 4% was large.

It was not possible to make as complete and perfect separation when the fine sand was in excess as it was when the coarse was in excess.

When the proportions approach equal weights, and the volume of the fine sand is somewhat in excess of the volume of the coarse sand, it does not seem possible to completely separate any considerable portion of either sand from the other by shaking, even though a variation in the mixtures may be clearly evident to the eye. As segregation is mainly due to size, it would seem desirable, as is quite generally recognized, that materials should be reduced to approximately the same size before mixing. To produce a theoretically perfectly divisible mixture, the material forming the smaller proportion should be so fine as to give the same number of particles as the material forming the larger proportion. For instance, if there is 90% of one material and 10% of another material, the latter should be divided so as to be one-ninth of the size of the former. As opposed to this is the fact that this subdivision, which permits a more perfect mixing, at the same time would produce, owing to a difference in size, an increased tendency towards segregation.

An illustration as to the effect of possible segregation, as it may apply to a cement mixture, follows:

Suppose a cement mill quarry carries stone which varies in calcium carbonate contents from 71.2% to 90%. Suppose it is desired to get a mixture of 74%, and suppose we take the extreme ranges of composition:

(1)	85 parts of 71.2% rock	60.50%
	15 parts of 90% rock	13.50%
		74.00%

Now suppose that by mistake, or intention, we only use *half* as much of the purer rock as we should, and replace it by the same amount of the leaner rock, we get the following equation:

(2)	92.5 parts of 71.2% rock	65.85%
	7.5 parts of 90% rock	6.75%
		72.61%

The amount of calcium carbonate only differs from the standard by 1.39%, though there has been used but half as much of one stone as should be used.

Now, taking the same mixture, which averages the desired amount of lime carbonate, and assume that owing to the difference in chemical composition the stone which is smaller in amount is also softer and breaks up into smaller pieces, so that the diameter of the particles is, roughly, one-half of the diameter of the particles of leaner material. We have shown that by merely shaking and segregating such a mixture it may be divided into two parts, one (55% of whole) carrying 99.2% of coarse, and .8% of the fine; and the other 45% of the whole carrying 67.5% of the coarse and 32.5% of the fine. Or by segregation we could get two portions represented by the following equations:

(3)	$99.2 \times 71.2 =$	70.63
	$.8 \times 90 =$	.72
		71.35

and—

(4)	$67.5 \times 71.2 =$	47.36
	$32.5 \times 90 =$	29.25
		76.61

Either varies from the desired amount more greatly than the variations caused by leaving out one-half of one of the ingredients. Of course, where there is no difference in chemical composition between the large and the small particles, the bad effects of segregation are less apparent, unless the difference in size is in itself objectionable, as is the case of the difference between lump coal and fine coal. But in nearly all cases there is a difference in composition between the larger and the smaller particles, and unless one has actually determined this difference, it is impossible for him to realize what segregation can do to him. It will often be found that the segregation due to passing material through a mill will give a greater variation in grab samples than differences due to the variations in the way in which the face of a quarry or mine is worked.

In the handling of dry material through a mill, where it may be crushed, transported, dried, ground and stored, and of which a portland cement mill is a typical example, there is commonly a greater or less storage in bins or tanks between each operation. Every time the material is moved or handled in any way there is a chance for segregation, or rearrangement of the proportion of the particles; but it seems of peculiar interest to consider the effect of tanks as segregating or mixing devices.

A circular glass tank was provided which was 8 in. long and 3½ in. in diameter, through the sides of which the movement of the material could be observed.

This tank having been filled with two kinds of sand in thin alternate layers, the mixture was drawn from the bottom in small portions (which represented in all cases from 1/12 to 1/28 of the entire amount in the tank), which were weighed and separated by sieving. These tests were repeated many times.

The shape of the bottom of the tank was varied and the mixture was drawn through openings which in the several tests differed in number and size. Every slight change produced some difference in the result, and the balance was so delicate that it was almost impossible to get closely co-ordinate results with any two tests done in apparently exactly the same way; but in general a well defined tendency or rule of segregation was shown.

Assuming that the tank was uniformly filled with thin alternate layers of coarse and fine sand, the first sample taken from the tank would contain an excess of either the fine or coarse sand, depending upon which layer was put in first. The last that was drawn from the tank invariably carried an excess of the fine material incidental to this material lagging behind and settling down to the sides of the tank. But ignoring these first and last samples and *assuming that the tank is full of approximately uniform material,* there might properly be said to be a gradual decrease from a maximum of coarse material, in the first half that was drawn, to a minimum of coarse material in the last half that was drawn; and the change roughly from an excess of coarse to an excess of fine always took place when the tank was *approximately half empty.*

A typical result when these materials were used in equal proportion by weight, distributed uniformly in layers in the tank and drawn through a single hole in the bottom, as described, is shown in Test 1. Holes differing in size were tried, and also differing in number. When three holes were put in the bottom of the tank, from which the material was drawn equally (these holes being roughly half way between the circumference and the center), the material was seen to mill down at three points and the extreme of variation was reduced somewhat upon the principle of probabilities. But none of these methods seemed to modify the general trend as indicated above. (Test 2.)

If two tanks are filled in the same manner, drawn at the same time in equal amounts, which amounts are mixed together, there is a very marked decrease in the extreme variation or segregation. (Test 5.) But this change also simply reduces the probability of two high readings of large sand coming together and is not sufficient to affect the general tendency for the first half drawn from tanks containing uniform mixtures to contain a majority of large material. Recognizing this fact, averages were made of the lower half of one tank with the upper half of an adjoining tank, which still further reduces the extreme variations. In other words, if one had two tanks filled and had drawn half from one tank before starting the second tank, the discharge from the two tanks passing into a common conveyor, and had drawn the second tank half way down before starting the third tank, etc., the extreme variation is considerably reduced, of which Test 6 will give an illustration.

The above tests, however, *are all on the assumption that the material is uniformly distributed in the tank.* This was practically impossible by any method I was able to employ, except by taking very small portions of each sand and carefully distributing it in layers. But a very great increase in uniformity can be brought about by filling into a tank so that it is scattered all over the horizontal surface as it falls. If a belt conveyor carrying a stream 18 in. wide and 3 in. thick feeds into a tank so that the material is uniformly distributed, it would take 470 ft. of the flow to cover a tank 30 ft. in diameter with a layer 3 in. thick. To do this would be to fold the stream on itself every 470 ft. and thus be an enormous aid to mixing, or regularity, in the tank as a whole. It would seem to be reasonable, and was confirmed by experiment, that the mere dropping of material into a tank at one point produces excessive variation, far greater in fact than the segregation (or mixing) due to withdrawing uniformly mixed material from a tank. In fact, this is the most serious cause of segregation, and every effort should be made to avoid it. (Tests 7, 8, and 9.)

When material is drawn from a tank, you get the resultant of the segregation (or mixing) due to filling, and the segregation (or mixing) due to drawing. The following test will illustrate this: The sands were put in a bottle in equal weights and mixed as thoroughly as possible by irregular agitation. It was evident to the eye that this mixture was imperfect. When it was drawn from the inverted bottle through a hole in the cork, it was evident, from our former tests, that a second change or segregation took place. When the stream dropped into the tank, another and probably the most serious segregation took place. It is most unfortunate that we should commonly, by our method of filling tanks, deliberately separate or segregate the materials.

If material is allowed to fall perpendicularly in the center of a tank, a distinct and definite form of segregation takes place. (Test 8.) The fine material collects in a vertical column in the center.

If the material is allowed to fall perpendicularly down one side of the tank, another very marked change is shown in the form of segregation. As before, the condition is the same all the way up the tank, and the fine material not only sticks to one side of the tank, but builds up on one side of the tank, while the coarse material flows to the other. (Test 7.)

If the tank is filled by a chute, commencing at one side of the top of the tank, inclined at such an angle that the material approximately will strike the opposite side of the base when the tank is empty, it is obvious that, as the tank fills, the point of deposition is continually changing and the slope of the deposited material is first in one direction and then in the other. It was hoped that this method of filling would be an advantage. But the results were disappointing. (Test 9.) The result of this method of filling seemed to be sufficient to reverse the tendency for an excess of the coarse material to be found in the first half drawn from the tank, and numerous experiments showed that, under these conditions, the bulk of the first half drawn from the tank contained an excess of the fine material, and the bulk of the second half drawn from the tank contained an excess of the coarse material. While this reversal was shown for this method of filling, the tendency for the first half drawn from the tank to be systematically different from the second half was maintained, so that again in drawing tanks, which have been filled in the same manner, the greatest possible aid to uniformity would be to draw from a half emptied tank and a full tank simultaneously, and when the second tank had been half emptied, to commence on a third.

The diagonal method of filling, however, seemed to lesson the danger of extreme variation in successive samples, as would naturally be expected from a consideration of the way in which the point of deposition is continually changing in a horizontal line.

All of these forms of segregation, due to filling, can be very largely avoided by scattering or distributing the stream over the tank.

A change in the shape of the bottom of the tank instantly showed some change in the character of the segregation due to drawing. A cone bottom, with sides very much steeper than the natural slope of the material, seemed to extend the movement down the center through a larger range and aided in mixing, or reduced the segregatian. The effect of differently shaped bottoms is illustrated in Tests 11 and 12.

As has been pointed out above, drawing from any tank produces segregation. If drawn from two openings at once, on the law of probabilities, the variation in separate samples is reduced. If drawn from two tanks at once, it is still further reduced. If drawn from a full tank and a partially emptied tank at the same time, the variation is still further reduced. But these aids to uniformity are subordinate to the segregation produced by dropping material into a tank. When it is realized that tanks may be 50, 60, or 80 ft. high, the chances for excessive variation due to the method of filling must be recognized. This can be largely overcome by distributing over the horizontal surface of the tank as it is filled.

Based on these tests, it was concluded that the most perfect use of tanks to reduce segregation and cause them to act as mixing devices would be to distribute the material uniformly over the horizontal surface of a tank; to draw from two tanks at the same time; to draw from the bottom of one tank while drawing from the top of another; and to refill the tanks before they got quite empty.

What seems to be a new and valuable modification of this is to divide a tank into two or more divisions by a longitudinal partition which stops far enough above the discharge orifice to insure perfectly free movement in either division. Such a tank with three divisions was tried out with quite satisfactory results, of which the following is a description:

The sands in equal amounts by weight were mixed in a bottle by agitating and marked segregation was visible to the eye. The bottle was inverted and the mixture allowed to flow out through a hole in the cork. Under such circumstances, as was shown by the former test, many portions coming from the bottle would show a variation of over 20% from the average in terms of the average. The divisions were filled to different levels and the material distributed by moving the bottle as the material ran out.

Samples were then taken representing 1/20 capacity of the tank as the mixture was drawn from the three divisions at the same time into a common channel. As each division got approximately empty, it was filled with a new mixture. Out of 36 samples, 30 in number (over 83%) varied from the mean, in terms of the mean, by less than 5%; four were between 5% and 10%, and one exceeded 10%. Of all of our experiments, this method gave by far the best results with the mixture used, and indicated that the procedure followed was probably the best possible. Repeated tests gave similar results.

In all our tests we were impressed with the fact that if an empty tank were filled and then a sample, representing say one-twentieth of the capacity, was drawn out, this first sample always gave an extreme variation from the mean. If the tank were drawn empty, the last two samples also always gave a wide variation. It was found that *by never drawing the tank more than nine-tenths empty, these extreme variations could be reduced to normal.* In other words, by giving up 10% of the storage capacity of a tank, the extreme irregularities due to filling an empty tank and drawing a tank empty will be avoided.

As material gets finer, the tendency to segregation is reduced; but is still active and appears to follow the same general rule. With very fine material, the tendency to roll is reduced, and the material collects in masses and then slides. When it is mixed it is more apt to "stay put." Possibly when dry fine material is agitated together, electric attraction due to friction may come into play. But still the same tendency was disclosed and to an important extent.

If portland cement, about 75% or 80% of which will go through a screen with 40,000 holes per sq. in., is dropped a distance of say 8 in. through a funnel, so as to strike at one point, the larger visible particles will be seen to sink into the surface of the finer material and form little craters, with vertical sides of finer material, and then after the pile has built up a ridge it will suddenly slide and flatten out. Tests showed that there was a marked difference in fineness between the outer edge, the intermediate section, and the center. The following was one of the results, the samples being obtained by pushing cylinders down through the pile so as not to disturb it.

Outside	23.6% caught on 200 mesh
Between	22.7% caught on 200 mesh
Center	21.3% caught on 200 mesh

If this happens in a fall of 8 in., how much more must be the segregation when material is dropped in a tank from a height of 60 ft. or 70 ft.? Based on the tests with coarser material, cement and other fine material ought to be fed into a tank in such a way as to allow it to fall evenly over the bottom; ought to be drawn from two tanks at once; and the tanks should be in series so that the second tank would commence to be drawn on when the first is half empty, and the third when the first is empty, and the second half empty, and so on. As has been shown, the effect of several tanks can be produced in one tank by having it divided longitudinally into two or more divisions.

I have had an opportunity of seeing tested out in actual practice the value of tanks or silos in correcting longitudinal irregularities in a stream of fine dry material (80% through 200 mesh), and the further reduction due to drawing two silos at the same time. The extreme variation in chemical composition is usually cut in half by passing the material through these silo tanks. A reasonable inference is that if the material were passed through two more silos in the same way the variation would again be cut in two.

But the greatest variation due to segregation is with going to each machine would be greatly reduced. The coarser dry material, and where there is a great difference in the size of the particles, and the strongest impression made on me by these tests is as to the extreme segregation incidental to the common method of dropping material into a deep tank and allowing it to impinge in a vertical line. This always produces excessive segregation, whether the material is fine or coarse, but is, as explained above, less when the material is very fine. It would seem to be the proper thing to make provision to insure a fair distribution of all material which is dropped into a tank, and it does not look like this would be difficult.

Among those industries which are peculiarly affected by the problem discussed is the portland cement industry, the manufacture of which is dependent upon the uniform mixing of dry materials which at certain stages of the operation differ greatly in size and composition. Anything which would add in any appreciable degree to the uniformity of the fine material which finally goes to the kilns would immediately be reflected in reduced cost, increased output, and improved quality of the finished material. I am encouraged to believe that a more thorough study of the question of segregation will accomplish valuable results in the industry.

The great claim for the wet method of manufacturing portland cement is the uniformity of the mix, and I am satisfied that if a concerted effort is made, in the light of these investigations, equal uniformity can be secured by the dry method.

The following consideration of a few points in the flow sheet of a theoretical portland cement plant, illustrates the possibility of segregation and the effects which might be expected.

Suppose the stone starting from the quarry containing exactly the right composition, but consisting of material some of which is high in lime and is relatively hard, some of which is low in lime and is relatively soft, and some of which consists of the clay stripping carrying practically no lime and very fine in its subdivisions. The material lands at the big crusher in a perfect state of average mixture. Every carload is, as an average, exactly the right composition. It is dropped into the big crusher and immediately the fine material and the softer material will go through very quickly, and the larger material is slower in passing through. The result is that the stream immediately divides itself into alternate sections of high lime and low lime material, and as it goes into storage we have seen that this separation is still further emphasized. If stored in a tank and allowed to fall at one point, we have shown that the segregation in such cases is such that if drawn from any tank in amounts representing, say, 1/20 of the entire capacity of the tank, you are certain to get material, some of which will carry from 60% to 70% of fine material, and from 40% to 30% of the coarse material, and some of the samples will be reversed. This process is taking place continually. If, however, in feeding into these tanks, the material is so distributed as to be spread over the tanks in layers, this segregation is greatly reduced, and if, after spreading in layers, two tanks are drawn at once, the segregation is still further reduced. If the tanks are filled irregularly so that the second half of one tank is being drawn while the first half of the other is being drawn, the variation is still further reduced. Uniformity, or lack of it, at this point must be a factor in the capacity of the hammer mill, or other disintegrator, which then crushes up all of the material to ¾ in. and under.

The material now goes to the dryer. Assuming it reaches the rotary dryer in a state of perfect uniformity (which we have shown is commonly not the case), the same material must come from the dryer as it is fed to it. A natural assumption is that a revolving cylinder must mix the material at least across its longer axis, but this is not true, as any regular movement increases segregation. The fine material collects together in a line parallel with the large axis of the dryer. This segregation is, however, a matter of little moment, as it is across the direction of the stream and we get out of the dryer what we put in; but it is only referred to to correct the impression that such revolving cylinders are of any value for the purpose of mixing.

If the dry stone is now fed into tanks, we have exactly the same problem as we had in the coarser stone tanks and exactly the same segregation will take place. This segregation does not continue indefinitely, but the tendency is always towards the formation of a certain amount of material which reaches the extreme segregation which we have shown to be possible. But even if an uniform mixture is fed to a tank by dropping into it at *one point*, and if the material is then drawn out at *one point*, you can be very certain that the stream of material which comes from the tank, when considered in amounts which represent a sensible proportion of the tank as a whole, will vary often, in the proportion of coarse and fine material, by more than 20% from the mean, in terms of the mean.

I had an opportunity once to note the material coming from a tank supplying a poidometer (or weighing machine) belt. This tank was being filled by a bucket elevator, and, at the time I examined it, the tank was practically empty, so that each bucketful was delivered on the belt with the segregation incidental to its fall into the tank. It was perfectly obvious that one side of the belt carried principally large material, and the other side of the belt carried very fine material; and an analysis showed a difference of 4% in carbonate of lime between the two sides of the stream on this belt.

Assuming that the material comes from the poidometer or weighing device (where the mix is corrected by the addition of material which is different in specific gravity, size of particles, and character of the surface), giving a perfect average for the day, but varying greatly from hour to hour as an inevitable result of the segregation in handling referred to, it now goes to the tanks supplying the mills which pulverize the raw materials. Here it conforms to the requirements which these tests have shown are most conducive to uniformity. As a rule, the raw material tanks are filled to an irregular height, and a number are being drawn at the same time. The average of the stream coming from these tanks would tend, first, to correct the broad irregularities incidental to the variation in the stream itself. Next, it would tend to correct the irregularities due to segregation from filling, and also tend to correct the segregation due to drawing, by drawing from a number of tanks at the same time. The ground material from these mills is fed into a common conveyor. The greatest aid to uniformity in cement manufacture is the mixing which comes from passing through many tanks to the grinding machines at this point. But great uniformity could be produced. It is certainly desirable that the variation in the material being fed to each machine should be as small as possible. This would not only enable the machine to work more efficiently, but would be of immense service in reducing the variation in the combination stream coming from the raw grinding mills. If, therefore, the stream were evenly distributed in each raw mill tank, the result is obliged to be of advantage. If also each machine were fed from two tanks or from a tank which had several divisions filled alternately, the variation in the stream efficiency and capacity of the machine would be increased, and the uniformity of the product would be increased.

The machines themselves really accomplish very little in the way of mixing, because of the small contents of the machine and the fact that the material is being fed to them and drawn from them continuously. The real mixing devices are the tanks which feed the machines.

Passing from the grinding machines, the finely ground raw mix is sometimes, and always with advantage, delivered into silos, or storage tanks. This is especially desirable where the correction made at the raw mix scales is necessarily several hours behind the stream to which the correction is applied. It enables the correction to catch up, and thus permits an overlapping of the stream in a longitudinal direction. It has been found in actual practice that by passing a stream through a single silo, first filling and then drawing, the maximum variation is reduced. This is not true if drawn from the silo as rapidly as it is put in. It has also been found that by drawing from two silos at the same time, the extreme variation could be greatly reduced. Roughly speaking, the maximum variation between the stream going to the silos and that coming from the silos will be reduced to about one-half, if drawn from two or more silos at the same time, and the silos have been drawn to unequal heights.

It is probable that in the ordinary operation of the silos, to some extent at least, the filling and the emptying conforms to what my experiments show to be best, and that is, that the lower portion of one tank is commonly being withdrawn while the upper portion of another is being withdrawn. But I am satisfied from these tests that if this is watched carefully and if the silos are never fully emptied, a further reduction of variation can be produced. I am further firmly persuaded that if provision is made for distributing the material uniformly into the silos in horizontal layers, the variation will be still further reduced. A large amount of money is expended in producing portland cement by the wet method of preparing the raw mix, the principal claim for which is that it conduces to greater uniformity. But until the above methods are fully tested out in dry grinding, it is not proper to say that similar uniformity cannot be reached by that method of manufacture.

I have referred to the portland cement manufacture as typical of an industry, in which the question of segregation is of great importance, but it is obvious that the number of industries in which this is a factor is very great. I cite a few of them:

SYNOPSIS OF TESTS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of samples	19	19	12	12	12	12	14	15	28	15	15	15	14	15	15
Average variation from mean in terms of mean %	14.2	10	11.5	16.9	7.6	5.0	21.9	21.8	18.1	10.6	6.5	9.7	4.8	4	3.4
Number of samples varying from mean, in terms of mean, more than 5%	18	13	9	10	6	6	12	15	26	12	7	12	6	9	4
10%	14	8	6	10	3	0	10	11	23	6	4	7	2	0	1
15%	10	4	3	5	3	0	9	10	20	3	2	3	0	0	0
20%	4	2	2	4	0	0	9	8	10	1	1	2	0	0	0
25%	1	1	1	3	0	0	7	3	4	0	0	1	0	0	0
30%	0	0	1	1	0	0	7	3	3	0	0	0	0	0	0
35%	0	0	0	0	0	0	2	3	1	0	0	0	0	0	0

1. Tanks filled by even distribution and drawn from one opening.

2. Tanks filled by even distribution and drawn from three openings.

3 and 4. Tanks filled and drawn in substantially the same manner.

5. An average gotten by combining the corresponding samples from 3 and 4.

6. An average gotten by combining the samples from the upper part of 3 with the lower part of 4, and vice versa.

7. Tanks filled by dropping material at one side and emptying through one hole in bottom.

8. Tanks filled by dropping material in center. Emptied through one hole.

9. Tanks filled by chute causing material to strike angle between side and bottom on opposite side. Emptied through one opening.

10. Tanks filled by even distribution. Emptied through one hole in flat bottom.

11. Tanks with vertical walls, 60° conical bottom, one opening.

12. Tanks with vertical walls, flat bottom, one opening.

13. Tanks filled by even distribution, wtih two sections and emptied through one hole.

14. Tanks filled by even distribution with three sections and emptied through one hole.

15. Tanks with three sections filled to different levels.

Continuing to consider portland cement as typical of an industry in which dry material in large quantities is handled and mixed and ground, and in which very exact mixture is necessary for success, I would call attention to the fact that the same problem applies to the question of the clinker, or burned material, and of the finished, or final ground product.

Assuming that exactly the same material is delivered to many kilns, there is certain to be a difference in the product from several kilns. More than that, the clinker will differ greatly in size. This difference in size measures to some degree at least differences in chemical composition, produced by segregation in the kilns, and very considerable differences in physical condition brought about during the clinkering process. If you separate the large clinker and the fine clinker, it is easily shown that there is considerable difference in both their physical and chemical qualities, and in the physical and chemical qualities of the cement which may be made from them.

We have, therefore, exactly the same problem here that you have with the raw material. We have a segregation when the material is dropped on, and taken from, the pile of clinker, and we have a segregation when the material is fed into the tanks and from the tanks to the grinding mills. As before, the mills which are used for grinding the clinker, together with their accompanying tanks, are valuable mixing devices reducing these variations. And, as before, the clinker going to the individual grinding machines can probably be rendered far more uniform and the work of the machines far more efficient if the clinker is distributed over the surface of each tank and if it is drawn from two tanks at once, or from a tank having longitudinal divisions.

When the ground clinker which forms cement is stored in tanks, or "bins," the same proposition occurs again. Cement should be distributed by some device in comparatively uniform horizontal layers, and not allowed to drop at any one single point into a tank. When cement is dropped into a 60 ft. or 70 ft. bin, the best possible chance for air separation and segregation is offered. It should certainly be drawn from two points in the same tank at the same time, and, if this is done, a far more uniform product can be secured than can be secured if this precaution is not taken.

Coal for coke ovens. Or the handling of run-of-mine coal for all purposes, so as to have successive proportions fairly comparable. At present no two carloads of run-of-mine coal are approximately the same.

Irregular sized ore of all sorts, which may be stored in bins, and in which uniformity is an element of value.

Run of crusher stone, or bank-run gravel, used for various purposes, especially for all concrete work.

Fertilizer mixtures.

Concrete itself, after mixing. The segregation caused by handling can be greatly reduced.

Many other operations will occur to the reader.

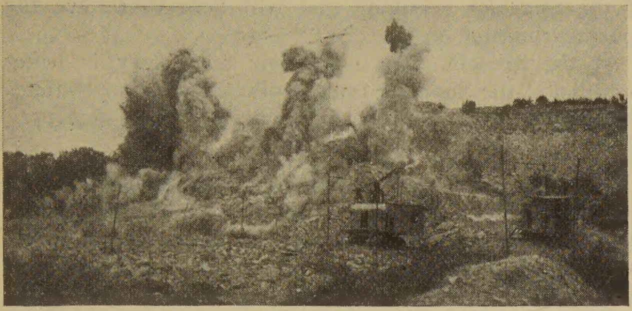
In this connection, reference is made to a paper by Robert H. Richards and Richard W. Lodge, read at the July, 1887, meeting of the American Institute of Mining Engineers, on "Experiments Illustrating the Descent of the Change in an Iron Blast Furnace," and also to "The Theory and Practice of Ore Sampling," by D. W. Brunton, which is found in Volume XXV of the Transactions of the same society.

My thanks are due to Miller Porter for performing the greater portion of the many tedious experiments.

Colorado Company Fires Big Blast

By E. J. Strock

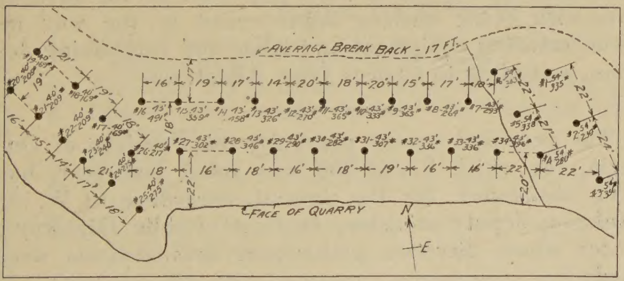
A spectacular view of a quarry blast is shown in the accompanying illustration of a 34-hole shot in the lime quarry of the Colorado Portland Cement Co., Portland, Colo. The rock being thrown as shown at the left end of the picture is equal to that of an ordinary blast in the lime quarry and the three columns of smoke indicate the size of the shot and make it look more impressive.



Spectacular Quarry Blast in Lime Rock Quarry of Colorado Portland Cement Co.

The shovel near the center of the picture is a 70C Bucyrus, and is ready to load the lime rock as soon as the shot is completed. The shovel on the right is ready to go up into the small arroyo just ahead of it and strip out some dirt brought down by storms. Along the bank of the arroyo shown just above the running board of the small shovel, dust is being forced out of the bank. This occurred where the dirt rested on the solid rock, as it was found later when the dirt was stripped.

Just over the top of the boom of the larger shovel is the floor of the shale quarry, as shale lies above the lime rock. The shovel quarrying shale is hidden by the smoke of the shot. The maximum face of the two quarries, one above the other, is about 130 ft., the highest point in the shale quarry being 86 ft. above the shale quarry floor, and the rest of the height being lime rock. The Arkansas River lies just to the left of the view in the picture. The river is crossed in conveying the rock to the plant.



Explosives Used	
Powder—"Titan D"	10,487 lbs.
Cordeau—Plain	561 lbs.
Cordeau—Corded	1,541 lbs.
Exploders—Electric	2

Duty of Powder	
Yards moved	27,440
Tons moved	55,703
Yards per pound powder	2.635
Tons per pound powder	5.312
Pounds powder per yard	.382
Pounds powder per ton	.188

The diagram gives the data on the shot. This is about as large a tonnage of powder as the Colorado company gets a chance to use in one shot. The shot was very successful. The drill and powder foreman in charge of the shot was A. F. Meyers, a man of many years' experience with powder in road making in the Rockies and in quarrying.

Pike's Peak is a trifle to the right of the picture and about 40 miles distant to the north.

Portland Cement Output in March

The statistics shown in the following table, prepared under the direction of G. F. Loughlin, of the U. S. Geological Survey, are based mainly on reports of producers of portland cement, but in part on estimates. The estimates for March were made necessary by the lack of returns from three producers.

Production, Shipments, and Stocks of Finished Portland Cement in March, 1922, and Preceding Months

Month	Production (bbls.)		Shipments (bbls.)		Stocks at end of mo. bbls.	
	1921	1922	1921	1922	1921	1922
Jan.	4,098,000	*a*4,291,000	2,539,000	*a*2,931,000	10,300,000	*a*13,316,000
Feb.	4,379,000	4,278,000	3,331,000	3,285,000	11,400,000	*a*14,142,000
Mar.	6,763,000	6,685,000	6,221,000	7,002,000	12,000,000	13,824,000
First quart'r	15,240,000	15,254,000	12,091,000	13,218,000	....	....
April	8,651,000	....	7,919,000	....	12,600,000	....
May	9,281,000	....	9,488,000	....	12,450,000	....
June	9,296,000	....	10,577,000	....	11,150,000	....
Second quart'r	27,228,000	....	27,984,000	....	....	....
July	9,568,000	....	10,301,000	....	10,414,000	....
Aug.	10,244,000	....	12,340,000	....	8,280,000	....
Sept.	10,027,000	....	11,329,000	....	6,953,000	....
Third quart'r	29,839,000	....	33,970,000	....	....	....
Oct.	10,506,000	....	12,114,000	....	5,348,000	....
Nov.	8,921,000	....	5,195,000	....	9,091,000	....
Dec.	6,559,000	....	3,697,000	....	11,938,000	....
Fourth quart'r	25,986,000	....	21,006,000	....	....	....
	98,293,000		95,051,000			

(*a*) Revised.

The Bureau of Foreign and Domestic Commerce, of the Department of Commerce, reports that imports of hydraulic cement in March amounted to 1,597 bbls., valued at $4,308. The total for 1921 was 122,317 bbls., valued at $388,828. The imports in March were from Mexico, 902 bbls.; France, 322 bbls.; Japan, 253 bbls.; other countries, 120 bbls. The statistics of exports of hydraulic cement in March are not available. The total exports in 1921 were 1,181,014 bbls., valued at $4,276,986.

Imports and Exports of Hydraulic Cement in March, 1922, and Preceding Months (*a*)

Month	Imports (bbls).		Exports (bbls.)	
	1921	1922	1921	1922
January	14,678	17,036	225,561	70,725
February	18,269	5,157	84,230	82,421
March	7,631	1,597	97,302	(*b*)
April	1,540	......	93,009	......
May	2,035	......	82,409	......
June	1,657	......	100,831	......
July	3,455	......	81,091	......
August	10,988	......	84,538	......
September	5,177	......	84,668	......
October	11,448	......	79,871	......
November	20,112	......	71,214	......
December	25,327	......	96,290	......
	122,317		1,181,014	

(*a*) Compiled from records of the Bureau of Foreign and Domestic Commerce.
(*b*) Exports in March are not available.

The Atlas Portland Cement Co., on behalf of its mill at Hannibal (Ilasco), Mo., has filed a complaint with the Interstate Commerce Commission protesting that the Chicago, Burlington & Quincy R. R. and other carriers named as defendants to the complaint, charge at present and will continue to charge and collect rates on cement sold "delivered" at points in Kansas which are greatly in excess of the rates charged by the railroads on cement from the plant of Dewey Portland Cement Co., a competitor of the Atlas, at Dewey, Okla. The Commission is requested to order the establishment of just and reasonable rates from Hannibal.

Men and Mills

Notes from the Field

The Sandusky Cement Co. plans to build a cement plant a few miles west of the city of Toledo, Ohio. This will really be a removal of the company's plant at Syracuse, Ind., with some additions to bring the outfit up to modern practice. The deposit at the point selected consists of over 400 acres of limestone, with cement rock and shale overlying it in the western portion. The quality of the rock, transportation facilities and the proximity of a market in Toledo are considered to have been controlling factors in the location of the plant.

H. W. Hardinge returned on the Olympic on March 29 from a business trip abroad. He spent about a month in England, France, and Belgium. Mr. Hardinge reports that business activity in Europe is apparently in better shape than in the United States. A more active interest in industrial problems seems to be taken, especially in the lines in which he is interested, namely, grinding, drying, and the application of powdered coal to boilers and steel plants.

W. F. Morris, formerly with the Cuban Portland Cement Co., is now with the Western States Portland Cemfent Co., at the Independence, Kans., plant, where he is general mill foreman.

Harry M. Zimmerman has been made chief chemist at the plant of the Western States Portland Cement Co., Independence, Kans., having succeeded H. J. Robertson, former chief chemist, who resigned.

The Bonner Portland Cement Co., Bonner Springs, Kans., has just completed the installation of a 1,000 kilowatt Westinghouse Parsons steam turbine. The company will generate its own power at the mill.

During the last three months there have been a number of changes in the sales organization of the Celite Products Co., manufacturers of heat insulation, etc. The policy of this company has been that increased business could be secured only by direct concentrated effort, and with this object in view, branch offices have recently been established in Boston, Buffalo, Cincinnati, and Minneapolis.

Dumerite, the new explosive recently put on the market by the DuPont company, is effecting reductions in blasting costs amounting to one-third and more, according to statements of users in quarry work submitted to the manufacturers. To a quarry company in the middle west is attributed the report that in its operations the new explosive is materially reducing blasting costs. In eastern quarries, equally good results have been obtained.

The Superior Portland Cement Co. is erecting four new cottages in Bellingham. These houses are being constructed from the small houses erected on Concrete Heights some years ago by the Washington Portland Cement Co. The cottages from the Heights have been moved at the rate of two or three each day, and three of the small houses are being combined into one large residence. Each of the small houses was raised and placed on a sled and taken in tow by a catapillar tractor. In the new location, after the cottages are joined together, the necessary alterations will be made to convert them into convenient dwellings. Doors and windows will be enlarged and porches added to make the new houses neat and attractive in appearance. When completed, the new cottages will be leased to employees of the Superior company and will help to relieve the housing shortage in the city.

At the present time some new machinery is being installed at the Superior cement plant, and other changes are being made to expedite the manufacture of cement.

By waiting a year, the Bath Portland Cement Co. has saved half a million dollars in the construction of its proposed new mill, to be located on the property it has purchased at Sandt's Eddy, and the calling for revised bids was the feature of the annual meeting, held early in February. Plans have been made for the construction of a second unit, similar to the first, located near Bath. The estimates a little more than a year ago totaled $2,250,000. It is estimated the unit can now be constructed for $1,750,000, and new tenders were asked for.

The stockholders elected the following directors: Louis Rafetto, Walter Dutton, John Barnes and Herbert Rufett, of Philadelphia, and Fred B. Franks, of Bath. These officers were elected: President, Louis Rafetto; first vice-president, Fred B. Franks; second vice-president, Walter Dutton; third vice-president, Herbert Rafetto; secretary, F. P. Hahneman, Philadelphia; treasurer, John Barnes.

It was reported that the installation of waste heat boilers had been completed, one of the foremost economies in the history of industry, by which at least 75% of the steam coal bill is saved. The sum of $300,000 was set aside for the improvement of the existing unit, chiefly for its complete electrification, including a 4,000 h.p. turbo generator. Electrification was about 30% completed when it was held up by the war, and the finishing of this work will increase the capacity of the mill to 4,000 bbls. a day. The new unit, which will have the same capacity, is to be a duplicate of the present one, with every modern improvement in the way of manufacturing equipment and labor and fuel-saving devices, according to advices from Allentown.

The proposed cement plant for the Province of Ontario, for which $1,000,000 was voted last year, has been abandoned for the present, according to W. A. McLean, deputy minister, Dept. of Public Highways, under whose direction preliminary arrangements were made.

The Petoskey Portland Cement Co. is now breaking ground for a new cement storage silo and packing house, capacity 100,000 bbls., to be used in loading boats from its own docks. The company is also putting up a raw storage structure with a capacity of 60,000 tons. This will be about all the new work that will be done at the Petoskey company's plant this year.

Fires were started under the boilers at the Nebraska Cement plant on March 22 and the whistle blew for the first time since closing down last fall. More men were being taken on each day and it was expected the full quota would be at work by the first of April.

The first good weather has caused an excellent movement of cement and probably one hundred car loads are moving out of the Lehigh district daily. A brisk season is anticipated.

The arrival of the steamer Mitchell at Alpena, Mich., on April 17 brought to an end a season of unusual winter activity, during which period the local plant of the Huron Portland Cement Co. was never closed, even for repairs of a few weeks, as was frequently the custom. Besides keeping the plant in full operation, the company has advanced its new construction to a point where some of the new buildings are commencing to take form.

The Wolverine Portland Cement Co., being the second largest producer in the state of Michigan, was allotted the third largest amount of cement to be used in road construction in the southern part of the state.

State Highway Commissioner Rogers, in making his allocation, recognized the fact that the mills located nearest to the work to be constructed should be awarded the cement contracts, in order that the contractors will secure the best transportation facilities.

The Hermitage Portland Cement Co., capitalized at $3,000,000, which will operate at Old Hickory, Tenn., filed its charter in the office of Secretary of State Ernest N. Haston recently. The company is chartered under the laws of Delaware, and the incorporators are given as T. L. Croteau, M. A. Bruce, and C. H. Maxwell, all residents of Wilmington, Del.

Glens Falls Portland Cement Co., Glens Falls, N. Y., is enlarging its capacity by installing more kilns, waste heat boilers, erecting a reinforced concrete building for the storage of stone and clinker, and by installing a new system for cooling clinker and also a new crushing plant. F. L. Smidth & Co., New York, are in charge of the work.

Because of improved conditions, the Olympic Portland Cement Co.'s cement plant reopened on April 1 with a crew of approximately 140 men, many of whom had been at work for several days in the company's quarries located between Sumas and Kendall, near Bellingham, Wash. Shipments by rail and water will begin in a short time.

The coal strike that recently went into effect will have no effect on the operation of the cement plant, in the opinion of Superintendent Krabbe. Nearly all of the coal the plant will use is shipped from Vancouver Island. In the course of a few days he expected to be producing 2,000 bbls. of cement per day.

H. G. Jacobson, superintendent of the accident prevention bureau of the Eastern District of the Portland Cement Association, was in charge of the annual meeting of the association at Allentown April 3. The purpose of the meeting was to discuss ways and means of preventing industrial accidents and to further safety measures in the cement industry.

The morning meeting was held in the Chamber of Commerce rooms, opening at 10 o'clock, for the superintendents and executives in charge of safety work at the various cement plants and departments, who are constantly devoting their efforts to the betterment of safety conditions and the elimination of working hazards. The meeting was devoted to a general discussion on safety methods, suggestions and changes.

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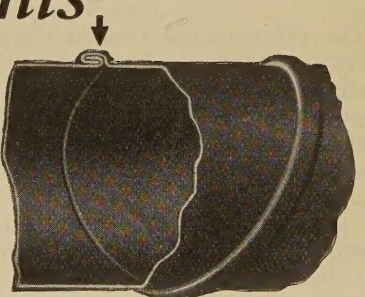

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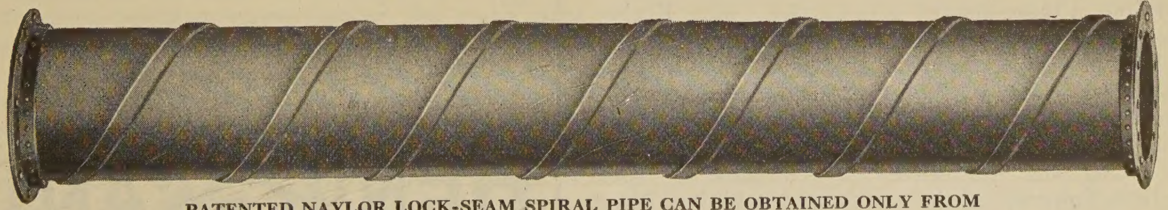

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The Connecticut Adamant Plaster Co., New Haven, is preparing to enlarge its plant by the addition of another calcining kettle and auxiliary equipment. Richard K. Meade & Co. have been chosen as the engineers for this work.

The new lime plant of the Bathurst Co., N. B., Canada, which was designed by Richard K. Meade & Co., was placed in operation the last week in March and has been running very satisfactorily.

The International Cement Co. has obtained a contract for work in Havana harbor calling for the delivery of from 75,000 to 100,000 bbls. of cement this year, according to reports from New York City. The company also has obtained a contract for furnishing cement for the vehicular tunnel under the Hudson river, which project will call for about 200,000 bbls. of cement.

Fred B. Franks, of the Bath Portland Cement Co., Coplay, Pa., and Mrs. Franks recently departed for Cuba.

The Texas Portland Cement Co., Dallas, announced its sales of cement during January, 1922, were greater than any year in January during the history of the plant.

The Pennsylvania Cement Co. again has placed a force of men at the work of removing topping and big steam shovels will soon be in action. Some of the familiar faces seen in Bath last year are back again with the contractors.

A "No-Accident Month" campaign will be carried on at the Tidewater Portland Cement plant the month of May, and everyone in the locality, whether employee or not, is expected to take an interest in this movement. Accident prevention is something of vital importance to every man, woman and child in no matter what walk of life, it is pointed out.

The International Cement Corporation, for the last quarter of 1921, reports gross sales of $2,482,752, against $3,324,501 in the previous quarter, while net income after all charges and reserves for taxes totaled $189,262, against $420,792 in the third quarter, $348,168 in the second quarter, and $499,655 in the first quarter.

The surplus for 1921, based upon the quarterly reports, was $1,457,880, equal to $.430 a share on the 324,693 shares of common stock outstanding. This is after allowing for the regular dividends on the preferred stock. The report shows that this result was reached in spite of the fact that the company did not benefit from any returns from the Knickerbocker Portland Cement Co., which was acquired last Summer, says the *New York Times*.

A. F. Krabbe, superintendent of the Portland Olympic Cement Co.'s plant at Bellingham, Wash., has just returned from a three months' trip abroad. Mrs. Krabbe was with her husband during the world jaunt.

At Lille he visited one of the largest cement plants on the continent. Lille was occupied by the Germans during most of the four years of war, and when it was regained by the French all of the machinery that was worth taking was removed by the Germans, he said. Since 1919, however, all the machinery has been replaced and the plant is now busily engaged in turning out its product to aid in the reconstruction of the rest of the city of Lille and the surrounding country.

In England, also, the cement industry is exceptionally busy, Mr. Krabbe found.

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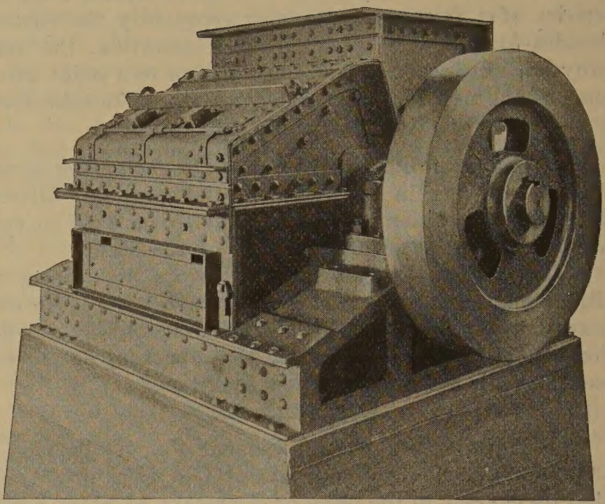

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